Distribution of this
document is unlimited

AD__________

TECHNICAL REPORT
67-67-FD

Ad652911

CHANGES IN TBA VALUE OF MEAT UNDER CONTROLLED CONDITIONS

by

M. E. Bailey - V. C. Witte
G. F. Krause
University of Missouri
Columbia, Missouri

Contract No. DA19-129-AMC-638(N)

Project reference:
5174240625

Series: FD- 55

April 1967

Food Division
U.S. ARMY NATICK LABORATORIES
Natick, Massachusetts 01760

FOREWORD

Traditionally, beef and pork which are not strictly fresh have been used to make frankfurters and pork sausage. Such beef and pork show no visible evidence of either protein or fat degradation; however, the fat has deteriorated sufficiently to prevent frankfurters or pork sausage from surviving a year in freezer storage. This deterioration in fat cannot be reliably detected organoleptically. A chemical method (TBA test) of detection has been proven reliable.

The TBA test is an objective measurement of a type of deteriorative change in complex fatty foods which is associated with the appearance of unpleasant flavors and odors. It has a close correlation with the subjective organoleptic evaluation of oxidative rancidity. Its principal function is to eliminate the conflicts of opinion and the senses regarding the existing rancidity condition of the meat fat at the moment of inspection.

The TBA test performs this function by quantitatively determining the amount of oxidation products reacting with thiobarbituric acid to produce a red pigment with a fixed absorption spectrum. The optical density of the TBA--fatty acid reaction pigment is compared spectrophotometrically with the standard absorption curves of varying concentrations of a specific rancidity product, malonaldehyde. The TBA test does not measure the total carbonyls of rancidity, but there is a close correlation between the TBA test value and the ultimate appearance of a rancid odor and flavor in raw or cooked meats. The test method, itself, breaks down intermediate rancidity products which re-enter into the reaction.

The reliability of the TBA test to detect fat degradation which is not organoleptically evident is not questioned. Variations of the methods by which the thiobarbituric acid principle is applied have caused a lack of confidence among the knowledgeable and the naive. The successful use of one or more of the specific methods of applying the thiobarbituric acid (TBA test) principle as a Quality Control technique has proved its value to industry; its successful use as a Quality Assurance technique has yet to prove its value to the Government.

The probability of a successful application of the TBA test principle to Military Procurement would be enhanced by testing frozen samples. The absence of adequate information relating to the testing of frozen samples caused this investigation which was conducted by the University of Missouri, Columbia, under contract DA19-129-AMC-638(N) through funds allocated to the upgrading of Subsistence Specifications. Dr. M. E. Bailey served as

Official Investigator. His collaborators were V. C. Witte and G. F. Krause. Project Officer for the U. S. Army Natick Laboratories was R. L. Bustead, and alternate Project Officer was B. W. Gardner, Jr., both of Animal Products Branch, Food Division.

FERDINAND P. MEHRLICH
Director
Food Division

APPROVED:

DALE H. SIELING, Ph.D.
Scientific Director

W. M. MANTZ
Brigadier General, USA
Commanding

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF FIGURES

ABSTRACT

This report summarizes work done to determine the effects of cooler and freezer storage on TBA values of ground uncooked pork and beef and their relationship to pH and percent fat. TBA values of pork were determined by distillation and extraction methods and those of beef were determined by the latter method. The TBA values determined were relatively low during storage from 2 to 7 days at 38°F and from 1 to 7 days at -3°F. There were significant animal differences in beef and pork in TBA values, percent fat and pH. There were significant changes in TBA values due to 38°F -storage, pH and percent fat, but changes during freezer-storage were insignificant.

I. INTRODUCTION

The purpose of this research was to determine the effects of chilling and freezing on the production of certain oxidation products in beef and pork as measured by the TBA test.

The thiobarbituric acid (TBA) test has been used successfully by several investigators to measure lipid oxidation during short term storage of cooked meats, but its use as a measure of oxidative change in fresh meat from pork and beef has not been fully explored.

Food technologists have been searching for many years for a chemical index of fresh meat quality as it might change during chilling and frozen storage. Since the TBA test is considered one of the most sensitive tests for oxidative deterioration of fats, it was felt that it might serve as a useful measure of the storage potential of fresh beef and pork.

II. EXPERIMENTAL METHODS AND MATERIALS.

A. Processing of Meat from Animals.

Pork. Carcasses from 5 pigs were studied in these experiments. Three animals were purchased from the University of Missouri Testing Station at weights of 210±10 pounds. The other two animals were obtained from the Missouri Station Swine Farm at approximately the same weight. These animals were slaughtered at the University

of Missouri abattoir and chilled overnight at 38°F. The ham, picnic, Boston Butt and loin from the left side of each carcass were used in these studies. The surface fat and bone of the cuts were removed and the meat cut into approximately 1/2" cubes and mixed thoroughly. The tissue was then divided into 48 portions and packaged in polyethylene bags which were closed to minimize air space and clamped with metal clips.

Beef. Forequarters from 5 different cutter grade cows were purchased from a local packer after overnight chilling. The quarters were boned and divested of excess fat and connective tissue. The lean tissue was then ground through a 1/2" plate followed by thorough mixing; it was re-ground through a 1/8" plate and again mixed. Forty-eight one-half pound samples were packaged as described for pork.

B. Storage of Samples Following Processing.

The following storage conditions were used:

a. Storage at 38±2°F. for a period of 2 to 7 days.

b. Storage at -3±2°F. for a period of 2 to 7 days.

c. Storage at various combinations of the temperatures in a and b for a period of 2 to 14 days.

The design of the storage times is indicated in Table I (Appendix).

Table II is a description of the test load for each individual carcass. Each cycle was essentially completed prior to initiation of the next cycle involving another carcass.

Immediately before analysis, each frozen sample was ground without thawing through a 1/4" plate of a Universal No. 2 hand grinder.

C. Chemical Procedures Used.

TBA value analyses. All pork samples were analyzed for TBA value by two methods. The first method was that of Tarladgis *et al.* (1960). The second was as follows:

Twenty grams of comminuted meat were blended full speed for 1.5 minutes in a chilled stainless steel Waring blendor cup with 50 ml of 40°F.-extracting solution containing 20% trichloroacetic acid in 2M phosphoric acid. The resulting slurry was transferred quantitatively to a 100 ml volumetric flask with 40 ml water. The sample was diluted to 100 ml with water and homogenized by shaking. A 50 ml portion was filtered through Whatman #1 filter paper. Five ml of filtrate was transferred to a test tube (15 x 200 mm) followed by 5 ml of TBA reagent (0.005M in distilled water). The tube was stoppered and the solution mixed by inversion and kept in the dark for 15 hours at room temperature (approximately 25°C.). The resulting color was measured at 530 mu in a Beckman DU spectrophotometer.

TBA values of the beef samples were determined by the extraction procedure described above for pork. All TBA values were determined on two different portions of each sample and in turn, two replicate colorimetric analyses were made of each portion.

pH determinations. Single pH determinations were made on two different portions of each sample by the official A.O.A.C. procedure (1960).

Fat determinations. The quantities of fat were measured on two different portions of each sample by the method of Salwin *et al*. (1955).

D. Statistical Analyses.

Analysis of variance was calculated as outlined in Snedecor (1965). Significance of differences between means was determined by the method of Least Significant Difference (LSD) as used by Le Clery (1957). Correlation coefficients were computed as described in Ezekiel (1950) and linear regression curves were drawn as indicated in Snedecor (1965).

III. RESULTS AND DISCUSSION.

A. Mean Values for Chemical Constituents.

Mean values of TBA, pH and fat for the five pork carcasses are listed in Table III. Those for beef are in Table IV. It should be noted that in most series (A thru F), TBA values for unfrozen samples (2C-0F, 3C-0F, 4C-0F, etc.) were higher than those for corresponding fresh samples. This difference was undoubtedly due to the fact that extraction and distillation of the frozen samples was initiated prior to thawing of the samples. Surprisingly, these differences were greater for samples analyzed by distillation

than those analyzed by extraction. There may be some effect of freezing and thawing on availability of aldehyde in fresh samples. Preliminary study in this laboratory of fresh beef samples indicate that this assumption is true.

Mean values for pH were quite uniform and those for fat were variable as expected.

B. Statistical Differences in TBA Values of Pork Determined by Distillation.

Data from analysis of variance of TBA values of pork by the distillation method are given in Table V. There were significant animal differences in TBA values, there were differences due to cooler and freezer storage, and there was an interaction between cooler time and freezer time.

The mean TBA values determined by distillation during storage of samples for the individual pigs are given in Table VI. These data indicate that the mean TBA value for animal No. 1 was higher than those of the other animals and the mean TBA value for animal No. 4 was significantly higher than that of animal No. 3. Animals No. 1 and No. 4 were obtained from the Missouri Station Swine Farm and the other three from the Missouri Swine Testing Station. This may mean that diet influenced TBA values of these animals.

The effect of cooler storage at 38°F. on TBA values (distillation) of the five pork carcasses is shown in Table VII. The values increased progressively during storage at this temperature. The TBA value of the seven-day sample was significantly higher than

those of the remaining samples and the two-day sample was significantly lower than those of the 5, 6 and 7-day samples.

TBA values of the pork carcasses (Table VIII) changed very little during storage at -3°F. The differences between the mean TBA values of the non-frozen samples and those of the frozen samples were discussed previously.

The interaction of storage at 38° and -3°F. on mean TBA values of pork is shown in Table IX and in Figure 1 (Appendix). There were many significant interactions in TBA values due to storage at the two temperatures. These are easily seen in Figure 1 where the mean TBA values of the 5 pork carcasses for the different cooler times are plotted against days of frozen storage.

There were no significant differences in TBA values during frozen-storage for the individual cooler-storage times. However, there were significant differences between TBA values of frozen samples and those of non-frozen (0-F) samples. These data also indicate that the TBA values of samples stored for 2 days at 38°F. were different from those stored for 7 days at this temperature.

C. Statistical Differences in TBA Value of Pork Determined by Extraction.

Data from analysis of variance of TBA values of pork by the extraction method are given in Table X. As in the results from the distillation analysis, there were significant animal differences in TBA values. There were also differences due to cooler

and freezer storage, and there was an interaction between cooler time and freezer time.

The individual effects of animal differences, cooler storage, freezer storage and cooler-freezer interaction on TBA values as determined by the extraction method are shown in Tables XI thru XIII. In general, these results were similar to those for TBA values determined by the distillation method.

The interaction of storage at 38° and -3°F. on mean TBA values (extraction) of samples from the five pork carcasses is shown in Table XIV and Figure 2. These data indicate that there were significant interactions in TBA values due to storage at the two different temperatures. In general, the changes due to frozen storage were insignificant, but there were significant changes due to cooler storage. The decrease in TBA value of samples between 0 and 1 day storage time was undoubtedly due to extraction of the 0 day samples without prior freezing.

D. Statistical Differences in TBA Value of Beef.

Data from analysis of variance of TBA values of beef are presented in Table XV. There were significant animal differences in TBA values and there were significant differences due to cooler and freezer storage.

The mean TBA values determined by extraction during storage of samples from the individual animals are presented in Table XVI. All values for the different animals are significantly different.

This animal variation may be important in regard to use of the TBA value as an index of quality for this type of animal, although all values for these samples were still quite low.

As with pork, there was a gradual increase in TBA values of beef as storage progressed at 38°F. (Table XVII). After the third day of storage at this temperature, the daily increase in constituents detected by reaction with TBA were significant.

The apparent difference in TBA values during freezer-storage (Table XVIII) was due to inclusion of the sample 0-F which actually was not a frozen sample. Thus, there were no significant changes due to frozen-storage of TBA values in beef. The interaction of cooler and frozen storage of TBA values of beef is shown in Table XIX and Figure 3. There were significant variations in TBA values due to interaction at the two storage temperatures.

E. Statistical Differences in Fat of Pork and Beef.

Data from analysis of variance of pork and beef fat are presented in Tables XX and XXI, respectively. There were significant animal differences in fat of both pork and beef. The data also indicate that there were differences in pork due to cooler time and freezer time and differences in beef due to cooler time. There were also significant interactions between cooler time and freezer time for fat from the two species.

F. Statistical Differences in pH of Pork and Beef.

Data from analysis of variance of pH of pork and beef are

presented in Tables XXII and XXIII, respectively. There were significant animal differences in pH of both pork and beef. This was surprising due to the uniformity of pH values given in Tables III and IV, but the mean square error terms were extremely low for these analyses. These data reflect the reproducibility of the pH determinations for duplicate samples at each of the storage periods concerned.

There were also significant differences for pH of pork and beef due to freezer time and significant interactions between cooler and freezer time.

G. Correlations Between Two Methods of Determining TBA Values.

Correlations between TBA values determined by the extraction method relative to those determined by the distillation method for pork are shown in Table XXIV. There was considerable variation between the correlations for the individual animals. Higher correlations were obtained between data obtained by the two methods on samples that gave the highest results. The highest correlations among the individual cycles were for animals number one and four. These two animals were the ones obtained from the Missouri Station Swine Farm.

Data from the two methods of determining TBA values might have been more highly related if the TBA values had been of greater magnitude. The correlation was improved by removing values for samples (0-F) which were analyzed unfrozen.

The overall correlation between TBA values as determined by the extraction method relative to those determined by the distillation method for duplicate analyses of two separate portions from 240 individual pork samples (n = 960) was 0.845. The correlation obtained by using the average of the duplicate analyses (n = 480) was 0.846. There was essentially no difference between the two. The overall correlation between TBA values as determined by the two different methods with the (0-F) samples removed was 0.858 (n = 420).

The regression curve of TBA (distillation) with TBA (extraction) of samples involving 960 analyses from five pork carcasses is drawn in Figure 4.

H. Correlation Coefficients Between TBA Values and pH, Fat and Storage Time of Pork.

Extraction method. These correlations for pork are listed in Table XXV. There were significant correlations between TBA values and pH, fat, cooler storage and freezer storage for the individual animals. When data from all 5 animals were pooled, there were significant correlations between TBA values of samples and their pH and cooler storage time. It was apparent from the data concerning TBA values and actual freezer time that these two variables were not related significantly. The significant correlations for the individual cycles between TBA values and freezer time included 0-time storage (0-F) samples but these were not frozen samples. These samples from pork always produced greater

quantities of material that reacted with TBA, but as pointed out previously, this was because the samples were analyzed unfrozen. A corrected correlation involving removal of 0-F samples for the total (420) samples between freezer time and TBA values was -0.024. Correction for individual animal differences by pooling cross products and sum of squares of variables from the individual cycles did not significantly change the correlation results. Simple regression curves for the significant uncorrected correlations between TBA values and pH and cooler time of the compiled data (total) are drawn in Figures 5 and 6, respectively.

Distillation method. The simple correlations between TBA values as determined by the distillation method and pH, fat and storage time of pork are listed in Table XXVI. There were significant correlations between TBA values and the other variables within samples of the various cycles and for the total samples between TBA values and pH, cooler time and freezer time. The correlation of total samples (n = 420) exclusive of 0-F samples between freezer time and TBA value was -0.004. Correction for individual animal differences by pooling cross products and sums of squares of variables from the individual cycles changed the correlations somewhat. It was thought that this procedure would improve the overall relationships between the variables, but it only improved the correlation between TBA value and cooler time from 0.220 ($P>0.05$) to 0.254 ($P>0.01$). The strongest relationship was between TBA value and cooler time. Since the distillation data were similar to that of

the extraction data for pork, regression curves were not drawn of the latter results.

I. Correlation Coefficients Between TBA Values and pH, Fat and Storage Time of Beef.

These data for the TBA values of beef as determined by the extraction method are in Table XXVII. As with pork, when data from the individual animals was considered, the strongest relationship was between TBA values and cooler time but there were also significant correlations between TBA values and fat and between TBA values and freezer time. These were invariably negative indicating that the relationship between fat and TBA value was inverse. The correlation data for the compiled samples showed significant relationships between TBA values and pH, fat and cooler time.

Simple regression curves for the uncorrected correlation data between TBA values and pH, fat and cooler time are drawn in Figures 7, 8 and 9.

J. Coefficients of Multiple Correlations Relating Changes in Cooler Time, Freezer Time, pH and Fat With Changes in TBA Values of Pork and Beef.

The multiple correlations as measures of the combined importance of the several independent variables as related to TBA values

of pork determined by the distillation and extraction methods were respectively 0.416 ($n = 420$) and 0.437 ($n = 420$). The respective regression equations were:

$$\hat{Y} = 1.9352 + 0.0324\ (CT) - 0.0006\ (FT)$$
$$-0.3270\ (pH) - 0.0014\ (F) \text{ and}$$
$$\hat{Y} = 1.6460 + 0.0183\ (CT) + 0.0003\ (FT)$$
$$-0.2912\ (pH) + 0.0027.$$

The multiple correlation between the independent variables as related to TBA values of beef was 0.575 ($n = 420$).

The regression equation for the beef data was:

$$\hat{Y} = 1.0786 + 0.0093\ (CT) + 0.0008\ (FT)$$
$$- 0.1598\ (pH) - 0.0141\ (F).$$

CT = cooler time.

FT = freezer time.

F = fat.

IV. CONCLUSIONS

The extraction method used in these studies for measuring TBA values of raw meat from pork and beef is useful for routine analysis of constituents involved in this determination. The method is simple and more convenient than the distillation method.

The TBA values obtained for the raw meat studied were generally low, but there were significant variations due to animal differences.

TBA values of beef and pork increased significantly during storage at 38°F., but changes during freezer-storage (-3°F.) were usually insignificant. TBA values determined on unfrozen samples were significantly higher than those of frozen samples when the analyses were initiated prior to thawing.

Even though TBA values of pork and beef were significantly correlated with pH, cooler storage and percent fat, the correlations were quite low and in general accounted for only 5 to 15 percent of the total variation.

SUMMARY

TBA values, pH and percent fat were determined on ground, uncooked portions of five pork and beef carcasses during storage at 38° and -3°F. Distillation and extraction methods were used to determine TBA values of pork and the extraction method was used for beef. The relationships between the various chemical constituents were determined statistically.

Data obtained by using the two methods for determining TBA values of pork were highly related ($r = 0.845$, $n = 960$) and the correlations were greater for samples having the highest TBA values. The TBA values obtained for most of the samples analyzed were low compared to those reported in the literature for cooked meat.

There were significant animal differences in beef and pork in regard to their TBA values, percent fat and pH.

The major changes in TBA values of pork and beef samples occurred during storage at 38°F. There was a gradual significant increase in TBA values during storage of both types of meat at this temperature.

The data also indicated significant differences in TBA values of pork due to freezer (-3°F)-storage and significant interactions due to cooler and freezer storage. The TBA values of beef decreased significantly during storage at -3°F. However, these changes in both beef and pork were apparently due to inclusion of 0-time freezer storage samples in the statistical analyses. These samples were analyzed for TBA values without freezing and the values were significantly higher than those of frozen samples analyzed without previous thawing. Changes in TBA values during actual storage of both pork and beef at -3°F. were usually insignificant.

TBA values of some of the individual samples of beef and pork were significantly correlated with pH, fat, cooler time and freezer time. Pooling of data from all five pork carcasses resulted in significant correlations between TBA values and pH and between TBA values and cooler time. Similar results were obtained for beef, and there was also a significant negative correlation between percent fat and TBA values of these samples. In general, these correlations accounted for from 5 to 15 percent of the total variation.

The most outstanding result was that TBA values of both pork and beef increased significantly during storage at 38°F. but the values were still low compared to those most frequently reported in the literature.

V. LITERATURE CITED

Ezekiel, Mordecai. Methods of Correlation Analysis. John Wiley and Sons, Inc. New York, N. Y. pp. 146-158, 208-219 (1950).

LeClery, E. L. Mean Separation by the Functional Analysis of Variance and Multiple Comparison. U.S.D.A. - A.R.S. -20 -3, May (1957).

Official Methods of the A.O.A.C., 9th Ed., pp. 162 par. 13.027 (1960).

Salwin, H., I. K. Block and J. H. Mitchell, Jr. 1955. Rapid Determination of Fat in Meat Products. J. Agr. Fd. Chem. 3, 588.

Snedecor, G. W. Statistical Methods Applied to Experiments in Agriculture and Biology. The Iowa State University Press, Ames, Iowa. pp. 237-338 (1965).

Tarladgis, B. G., Betty M. Watts, Margaret T. Younathan and L. R. Dugan, Jr. 1960. J. of Am. Oil Chem. Soc. 37, 44.

VI. APPENDIX

TABLE I

DESIGN OF STORAGE TESTS

A	B	C	D	E	F
2C-0F	3C-0F	4C-0F	5C-0F	6C-0F	7C-0F
2C-1F	3C-1F	4C-1F	5C-1F	6C-1F	7C-1F
2C-2F	3C-2F	4C-2F	5C-2F	6C-2F	7C-2F
2C-3F	3C-3F	4C-3F	5C-3F	6C-3F	7C-3F
2C-4F	3C-4F	4C-4F	5C-4F	6C-4F	7C-4F
2C-5F	3C-5F	4C-5F	5C-5F	6C-5F	7C-5F
2C-6F	3C-6F	4C-6F	5C-6F	6C-6F	7C-6F
2C-7F	3C-7F	4C-7F	5C-7F	6C-7F	7C-7F

<u>Code</u>:

F = frozen storage at -3 ± 2^{o}F.

C = chilled storage at 38 ± 2^{o}F.

Number = days of chilled or frozen storage.

TABLE II

DISTRIBUTION OF TEST LOAD

Days After Start of Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Indiv.	None	2C-0F	2C-1F	2C-2F	2C-3F	2C-4F	2C-5F	2C-6F	2C-7F	3C-7F	4C-7F	5C-7F	6C-7F	7C-7F
			3C-0F	3C-1F	3C-2F	3C-3F	3C-4F	3C-5F	3C-6F	4C-6F	5C-6F	6C-6F	7C-6F	
				4C-0F	4C-1F	4C-2F	4C-3F	4C-4F	4C-5F	5C-5F	6C-5F	7C-5F		
					5C-0F	5C-1F	5C-2F	5C-3F	5C-4F	6C-4F	7C-4F			
						6C-0F	6C-1F	6C-2F	6C-3F	7C-3F				
							7C-0F	7C-1F	7C-2F					
Frequency of Tests	1	2	3	4	5	6	6	6	5	4	3	2	1	48 total

TABLE III

MEAN VALUES[1] OF TBA, pH AND FAT OF PORK

Storage Condition[2]	TBA Value		pH	Fat (%)
	Distillation	Extraction		
A				
2C-0F	.2836	.1417	5.6320	14.890
2C-1F	.2462	.1394	5.6240	15.070
2C-2F	.1852	.1052	5.6300	14.440
2C-3F	.1271	.0911	5.6580	17.040
2C-4F	.1558	.0818	5.6450	14.780
2C-5F	.1396	.0851	5.6480	14.390
2C-6F	.1315	.0818	5.6240	15.540
2C-7F	.1867	.0999	5.6030	13.550
B				
3C-0F	.6688	.1336	5.6280	11.250
3C-1F	.1824	.0894	5.6440	13.870
3C-2F	.1408	.0918	5.6680	14.780
3C-3F	.2060	.0946	5.6340	15.530
3C-4F	.1638	.0929	5.6520	16.180
3C-5F	.1794	.0964	5.6140	15.860
3C-6F	.2065	.1150	5.5940	13.050
3C-7F	.1414	.1014	5.6010	12.990
C				
4C-0F	.5222	.2098	5.6240	15.180
4C-1F	.1527	.1075	5.6780	13.500
4C-2F	.2046	.1230	5.6260	13.800
4C-3F	.1838	.1289	5.6680	15.310
4C-4F	.1746	.1056	5.6400	13.820
4C-5F	.2711	.1320	5.6160	12.150
4C-6F	.2267	.1318	5.6040	9.730
4C-7F	.1805	.1205	5.6920	16.590
D				
5C-0F	.4582	.2567	5.6100	15.440
5C-1F	.2415	.1370	5.6180	13.420
5C-2F	.2429	.1473	5.6360	15.060
5C-3F	.2613	.1273	5.6120	13.770
5C-4F	.2446	.1462	5.6200	13.280
5C-5F	.2657	.1609	5.5880	13.390
5C-6F	.2191	.1394	5.6420	16.060
5C-7F	.2106	.1334	5.6880	15.530

TABLE III CONT'D

Storage Condition[2]	TBA Value Distillation	TBA Value Extraction	pH	Fat (%)
<u>E</u>				
6C-0F	.5749	.3292	5.6340	13.740
6C-1F	.2224	.1439	5.6490	13.690
6C-2F	.2875	.1435	5.6120	15.980
6C-3F	.2780	.1636	5.6120	16.490
6C-4F	.2657	.1696	5.6360	14.650
6C-5F	.2690	.1441	5.6780	16.170
6C-6F	.2499	.1327	5.6640	16.540
6C-7F	.2306	.1571	5.6840	16.960
<u>F</u>				
7C-0F	.9332	.3751	5.6100	13.300
7C-1F	.4013	.2234	5.5940	12.450
7C-2F	.3096	.1708	5.6160	12.720
7C-3F	.3021	.1777	5.6180	14.850
7C-4F	.2867	.1691	5.6580	13.490
7C-5F	.2812	.1432	5.6960	14.130
7C-6F	.2995	.1725	5.6580	16.310
7C-7F	.3919	.2308	5.6940	15.680

[1]Values are means of duplicate analyses of samples from 5 carcasses.

[2]F = frozen storage at -3±2°F; C = chilled storage at 38±2°F.; Number = days of storage.

TABLE IV

MEAN VALUES[1] OF TBA, pH AND FAT OF BEEF

Storage Condition[2]	TBA Value Extraction	pH	Fat (%)
A			
2C-0F	.1111	5.5960	7.1300
2C-1F	.0983	5.6200	7.1500
2C-2F	.0925	5.6340	7.2300
2C-3F	.0988	5.6700	7.0700
2C-4F	.1048	5.6620	7.1800
2C-5F	.1068	5.6920	7.0900
2C-6F	.0961	5.6920	7.1600
2C-7F	.1033	5.7160	7.2000
B			
3C-0F	.1116	5.6100	7.0400
3C-1F	.0968	5.6470	7.1700
3C-2F	.0989	5.6910	7.1500
3C-3F	.1022	5.6640	7.1100
3C-4F	.1096	5.6980	7.2800
3C-5F	.1030	5.6820	6.8900
3C-6F	.1154	5.7260	7.0900
3C-7F	.1234	5.6880	7.3100
C			
4C-0F	.1200	5.6440	7.0200
4C-1F	.1101	5.6900	7.1700
4C-2F	.1197	5.6660	7.2100
4C-3F	.1190	5.7000	7.1800
4C-4F	.1301	5.6900	7.0900
4C-5F	.1270	5.7160	7.1000
4C-6F	.1219	5.6820	7.2400
4C-7F	.1224	5.6100	7.2200
D			
5C-0F	.1301	5.6700	7.1100
5C-1F	.1276	5.6800	7.2200
5C-2F	.1293	5.7000	7.2500
5C-3F	.1336	5.6960	7.0800
5C-4F	.1331	5.7240	7.2000
5C-5F	.1441	5.6700	7.2200
5C-6F	.1295	5.6240	7.2000
5C-7F	.1260	5.6420	7.1100

TABLE IV CONT'D

Storage Condition[2]	TBA Value Extraction	pH	Fat (%)
E			
6C-0F	.1348	5.6660	7.0600
6C-1F	.1344	5.6950	7.1900
6C-2F	.1384	5.6920	7.1700
6C-3F	.1640	5.7220	7.2200
6C-4F	.1315	5.6760	7.1000
6C-5F	.1367	5.6200	7.1000
6C-6F	.1433	5.6480	6.8800
6C-7F	.1514	5.7300	7.3000
F			
7C-0F	.1684	5.6720	6.9800
7C-1F	.1430	5.6900	7.0400
7C-2F	.1557	5.7280	7.1300
7C-3F	.1558	5.6820	7.2600
7C-4F	.1455	5.6240	7.0100
7C-5F	.1543	5.6390	7.3200
7C-6F	.1538	5.7240	7.3000
7C-7F	.1463	5.6980	7.2400

[1]Values are means of duplicate analyses of samples from 5 carcasses.

[2]F = frozen storage at -3 ± 2^{o}F.; C = chilled storage at 38 ± 2^{o}F.; number = days of storage.

TABLE V

ANALYSIS OF VARIANCE OF TBA VALUES (DISTILLATION) OF PORK

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance Level	
					1%	5%
Total	83.1031	959	0.0867	--	--	--
Cycle[1]	20.7230	4	5.1808	112.990	3.36	2.39
Cooler time[2]	4.4242	5	0.8848	19.298	3.06	2.23
Freezer time[3]	12.6353	7	1.8050	39.368	2.69	2.03
Cooler time x freezer time	3.6904	35	0.1054	2.299	1.74	1.49
Error	41.6302	908	0.0458	--	--	--

[1]Variation due to animal differences.

[2]Samples stored at 38±2°F.

[3]Samples stored at -3±2°F.

TABLE VI

MEAN[1] TBA VALUES (DISTILLATION) OF PORK

Cycle No.	Animal No.	N	Mean[2] TBA Value
1	1	192	0.5338 A
2	2	192	0.1946 BE
3	3	192	0.1341 BC
4	4	192	0.3258 DE
5	5	192	0.1648 BE

[1]Mean TBA values during cooler and freezer storage of samples from 5 pork carcasses.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.1918).

TABLE VII

EFFECT OF 38°F.-STORAGE ON MEAN TBA VALUES (DISTILLATION) OF PORK

Days[1] of Cooler Storage	N	Mean[2] TBA Value
2	160	0.1820 A
3	160	0.2361 BA
4	160	0.2395 BA
5	160	0.2680 B
6	160	0.2973 B
7	160	0.4007 C

[1]Cooler storage was followed by freezer storage from 0 to 7 days.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0165).

TABLE VIII

EFFECT OF -3°F.-STORAGE ON MEAN TBA VALUES (DISTILLATION) OF PORK

Days[1] of Freezer Storage	N	Mean[2] TBA Value
0	120	0.5735 A
1	120	0.2411 B
2	120	0.2284 B
3	120	0.2264 B
4	120	0.2152 B
5	120	0.2344 B
6	120	0.2222 B
7	120	0.2236 B

[1]Samples were stored at 38°F from 2 to 7 days prior to freezer storage.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0654).

TABLE IX

INTERACTION[1] OF STORAGE AT 38° AND -3°F. ON MEAN[2] TBA VALUES (DISTILLATION) OF PORK

Sample No.	0F	1F	2F	3F	4F	5F	6F	7F
2C	.2836	.2462	.1852	.1271	.1558	.1396	.1315	.1867
3C	.6688	.1824	.1408	.2060	.1638	.1794	.2065	.1414
4C	.5222	.1527	.2046	.1838	.1746	.2711	.2267	.1805
5C	.4582	.2415	.2429	.2613	.2446	.2657	.2191	.2106
6C	.5749	.2224	.2875	.2780	.2657	.2690	.2499	.2306
7C	.9332	.4013	.3096	.3021	.2867	.2812	.2995	.3919

[1] $LSD_{.05}$ = 0.1375.

[2] N = 20.

TABLE X

ANALYSIS OF VARIANCE OF TBA VALUES (EXTRACTION) OF PORK

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance Level 1%	5%
Total	17.8658	959	0.0186	--	--	--
Cycle[1]	6.9443	4	1.7361	204.970	3.36	2.39
Cooler time[2]	1.3777	5	0.2755	32.527	3.06	2.23
Freezer time[3]	1.2696	7	0.1814	21.417	2.69	2.03
Cooler time x freezer time	0.5822	35	0.0166	1.960	1.74	1.49
Error	7.6920	908	0.00847	--	--	--

[1]Variations due to animal differences.

[2]Samples stored at 38 ± 2^{o}F.

[3]Samples stored at -3 ± 2^{o}F.

TABLE XI

MEAN[1] TBA VALUES (EXTRACTION)OF PORK

Cycle No.	Animal No.	N	Mean[2] TBA Value
1	1	192	0.3061 A
2	2	192	0.1122 B
3	3	192	0.0827 C
4	4	192	0.1544 D
5	5	192	0.0732 C

[1]Mean TBA values during cooler and freezer storage.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0261).

TABLE XII

EFFECT OF 38°F.-STORAGE ON MEAN TEA VALUES (EXTRACTION) OF PORK

Days[1] of Cooler Storage	N	Mean[2] TBA Value
2	160	0.1032 A
3	160	0.1019 A
4	160	0.1324 B
5	160	0.1560 CB
6	160	0.1730 C
7	160	0.2078 D

[1]Cooler storage was followed by freezer storage from 0 to 7 days.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0264).

TABLE XIII

EFFECT OF $-3^{o}F$.-STORAGE ON MEAN TBA VALUES (EXTRACTION)OF PORK

Days[1] of Freezer Storage	N	Mean[2] TBA Value
0	120	0.2410 A
1	120	0.1401 B
2	120	0.1303 B
3	120	0.1305 B
4	120	0.1275 B
5	120	0.1270 B
6	120	0.1289 B
7	120	0.1405 B

[1]Samples were stored at $38^{o}F$. from 2 to 7 days prior to freezer storage.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0243).

TABLE XIV

INTERACTION[1] OF STORAGE AT 38° AND -3°F. ON MEAN[2] TBA VALUES (EXTRACTION) OF SAMPLES FROM FIVE PORK CARCASSES

Sample No.	0F	1F	2F	3F	4F	5F	6F	7F
2C	.1417	.1394	.1052	.0911	.0818	.0851	.0818	.0999
3C	.1336	.0894	.0918	.0946	.0929	.0964	.1150	.1014
4C	.2098	.1075	.1230	.1289	.1056	.1320	.1318	.1205
5C	.2567	.1370	.1473	.1273	.1462	.1609	.1394	.1334
6C	.3292	.1439	.1435	.1636	.1696	.1441	.1327	.1571
7C	.3751	.2234	.1708	.1777	.1691	.1432	.1725	.2308

[1] $LSD_{.05}$ = 0.0591.

[2] N = 20.

TABLE XV

ANALYSIS OF VARIANCE OF TBA VALUES (EXTRACTION) OF BEEF

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance Level	
					1%	5%
Total	2.6978	959	0.0028	--	--	--
Cycle[1]	1.6382	4	0.4095	538.816	3.36	2.39
Cooler time[2]	0.3144	5	0.0629	82.763	3.06	2.23
Freezer time[3]	0.0127	7	0.0018	2.368	2.69	2.03
Cooler time x freezer time	0.0392	35	0.0011	1.447	1.74	1.49
Error	0.6933	908	0.00076	--	--	--

[1]Variation due to animal differences.

[2]Samples stored at 38±2°F.

[3]Samples stored at -3±2°F.

TABLE XVI

MEAN[1] TBA VALUES (EXTRACTION) OF BEEF

Cycle No.	Animal No.	N	Mean[2] TBA Value
1	1	192	0.3061 A
2	2	192	0.1122 B
3	3	192	0.0827 C
4	4	192	0.1544 D
5	5	192	0.0732 E

[1]Mean TBA values during cooler and freezer storage.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0078).

TABLE XVII

EFFECT OF 38°F.-STORAGE ON MEAN TBA VALUES (EXTRACTION) OF BEEF

Days[1] of Cooler Storage	N	Mean[2] TBA Value
2	160	0.1015 A
3	160	0.1076 A
4	160	0.1213 B
5	160	0.1317 C
6	160	0.1418 D
7	160	0.1528 E

[1]Cooler storage was followed by freezer storage from 0 to 7 days.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0079).

TABLE XVIII

EFFECT OF -3°F.-STORAGE ON MEAN TBA VALUES (EXT[illegible]ION) OF BEEF

Days[1] of Freezer Storage	N	Mean[2] TBA Value
0	120	0.1293 A
1	120	0.1184 B
2	120	0.1224 B
3	120	0.1289 B
4	120	0.1257 B
5	120	0.1286 B
6	120	0.1267 B
7	120	0.1288 B

[1]Samples were stored at 38°F. from 2 to 7 days prior to freezer storage.

[2]Means followed by the same letter are not significantly different ($LSD_{.05}$ = 0.0082).

TABLE XIX

INTERACTION[1] OF STORAGE AT 38° AND -3°F ON MEAN[2] TBA VALUES (EXTRACTION) OF BEEF

Sample No.	0F	1F	2F	3F	4F	5F	6F	7F
2C	.1111	.0983	.0925	.0988	.1048	.1068	.0961	.1033
3C	.1116	.0968	.0989	.1022	.1096	.1030	.1154	.1234
4C	.1200	.1101	.1197	.1190	.1301	.1270	.1219	.1224
5C	.1301	.1276	.1293	.1336	.1331	.1441	.1295	.1260
6C	.1348	.1344	.1384	.1640	.1315	.1367	.1433	.1514
7C	.1684	.1430	.1557	.1558	.1455	.1543	.1538	.1463

[1] $LSD_{.05}$ = 0.0201

[2] N = 20.

TABLE XI

ANALYSIS OF VARIANCE OF PERCENT FAT OF PORK

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance Level 1%	Significance Level 5%
Total	46.9854	479	0.[illegible]1	--	[illegible]	---
Cycle	5.9352	4	1.[illegible]83	2[illegible]3	3.3[illegible]	[illegible].39
Cooler time[2]	[illegible]	5	0.3298	[illegible].698	3.06	2.23
Freezer time[3]	[illegible]93	[illegible]	0.21[illegible]	[illegible]091	2.69	2.03
Cooler time x freezer time	[illegible]	35	0.2242	[illegible].194	1.74	1.49
Error	30.0[illegible]52	42[illegible]	0.0[illegible]	--	--	--

[1]Variation due to animal differences.

[2]Samples stored at [illegible]2°F.

[3]Samples stored at [illegible]±2°F.

TABLE XXI

ANALYSIS OF VARIANCE OF PERCENT FAT OF BEEF

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance Level	
					1%	5%
Total	912.1198	479	1.9042	--	--	--
Cycle[1]	881.9224	4	220.4806	3561.880	3.36	2.39
Cooler time[2]	0.1267	5	0.0253	0.041	3.06	2.23
Freezer time[3]	1.0640	7	0.1520	2.456	2.69	2.03
Cooler time x freezer time	3.5081	35	0.1002	1.619	1.74	1.49
Error	26.4986	428	0.0619	--	--	--

[1]Variation due to animal differences.

[2]Samples stored at 38±2°F.

[3]Samples stored at -3±2°F.

TABLE XXII

ANALYSIS OF VARIANCE OF PORK TISSUE pH

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance Level 1%	Significance Level 5%
Total	3.1964	479	0.0[illegible]7	--	--	--
Cycle[1]	1.2737	4	0.[illegible]7	[illegible]02	[illegible].36	2.39
Cooler time[2]	0.027[illegible]	5	0.0055	1.536	3.06	2.23
Freezer time[3]	0.0515	7	0.0[illegible]74	2.[illegible]7	2.[illegible]	2.03
Cooler time x freezer time	0.[illegible]086	35	0.0[illegible]8	[illegible].458	1.74	[illegible]49
Error	1.[illegible]03	428	0.0[illegible]8	--	--	[illegible]

[1]Variation due to animal differences.

[2]Samples stored at 3[illegible]±2°F.

[3]Samples stored at -[illegible]°F.

TABLE XXIII

ANALYSIS OF VARIANCE OF BEEF TISSUE pH

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F	Significance Level	
					1%	5%
Total	3.6314	479	0.0076	--	--	--
Cycle[1]	0.5332	4	0.1333	22.593	3.36	2.39
Cooler time[2]	0.0246	5	0.0049	0.831	3.06	2.23
Freezer time[3]	0.0887	7	0.0127	2.152	2.69	2.03
Cooler time x freezer time	0.4579	35	0.0131	2.220	1.74	1.49
Error	2.5270	428	0.0059	--	--	--

[1]Variation due to animal differences.

[2]Samples stored at 38±2°F.

[3]Samples stored at -3±2°F.

TABLE XXIV

CORRELATIONS BETWEEN TBA VALUES (EXTRACTION) AND TBA VALUES (DISTILLATION) FOR PORK

Cycle	N	r	N[1]	r
1	96	0.8110	84	0.8745
2	96	0.2080	84	0.2533
3	96	0.3267	84	0.3351
4	96	0.8530	84	0.7649
5	96	0.4703	84	0.4945
Total	480[2]	0.8458	420	0.8580
Total	960[3]	0.8450	--	--

[1]The twelve samples from each cycle that were not frozen prior to analysis were excluded.

[2]Involves correlation of the averages of duplicate analyses of two separate portions from 240 pork samples.

[3]Involves correlation of two individual analyses of two separate portions from 240 pork samples.

TABLE XXV

CORRELATIONS BETWEEN TBA VALUES (EXTRACTION) AND pH, FAT AND STORAGE TIME OF PORK

Cycle[1]	N	pH	Fat	Cooler Time[2]	Freezer Time[3]
1	96	-0.383**	0.030	0.549**	-0.369**
2	96	0.064	0.256*	0.443**	-0.009
3	96	0.190	0.009	0.332**	-0.448**
4	96	-0.233*	-0.293**	0.529**	-0.282**
5	96	0.049	0.096	0.400**	0.198
Total	480	-0.295**	0.075	0.269**	-0.157
Total[4]	480	-0.139	0.003	0.348**	-0.202

**(P>0.01)

*(P>0.05)

[1]Different animals.

[2]Storage at $38 \pm 2^{\circ}$F.

[3]Storage at $-3 \pm 2^{\circ}$F.

[4]Effect of individual animal differences removed by pooling data from individual cycles.

TABLE XXVI

CORRELATIONS BETWEEN TBA VALUES (DISTILLATION) AND pH, FAT AND STORAGE TIME OF PORK

Cycle[1]	N	pH	Fat	Cooler Time[2]	Freezer Time[3]
1	96	0.436**	-0.124	0.397**	-0.462**
2	96	0.156	-0.136	0.279**	-0.281**
3	96	0.032	-0.195	0.126	-0.240**
4	96	-0.283**	-0.260**	0.324**	-0.281**
5	96	0.031	-0.006	0.648**	0.026
Total	480	-0.254*	-0.052	0.220*	-0.236*
Total[4]	480	-0.171	-0.105	0.254**	-0.272

**(P>0.01)

*(P>0.05)

[1]Different animals.

[2]Storage at 38±2°F.

[3]Storage at -3±2°F.

[4]Effect of individual animal differences removed by pooling data from individual cycles.

TABLE XXVII

CORRELATIONS BETWEEN TBA VALUES (EXTRACTION) AND pH, FAT AND STORAGE TIME OF BEEF

Cycle[1]	N	pH	Fat	Cooler Time[2]	Freezer Time[3]
1	96	0.183	0.008	0.278**	0.131
2	96	0.040	-0.080	0.620**	0.040
3	96	-0.019	-0.296**	0.144	-0.396**
4	96	-0.098	0.245*	0.611**	0.075
5	96	-0.111	-0.251*	0.850**	0.040
Total	480	-0.245*	-0.384**	0.332**	-0.002
Total[4]	480	-0.030	-0.065	0.743**	-0.041

**(P>0.01)

*(P>0.05)

[1]Different animals.

[2]Storage at 38±2°F.

[3]Storage at -3±2°F.

[4]Effect of individual animal differences removed by pooling data from individual cycles.

Figure 1
EFFECT OF -3° F.-STORAGE ON MEAN TBA VALUES (DISTILLATION)
OF PORK FOLLOWING CHILLING AT 38° F.

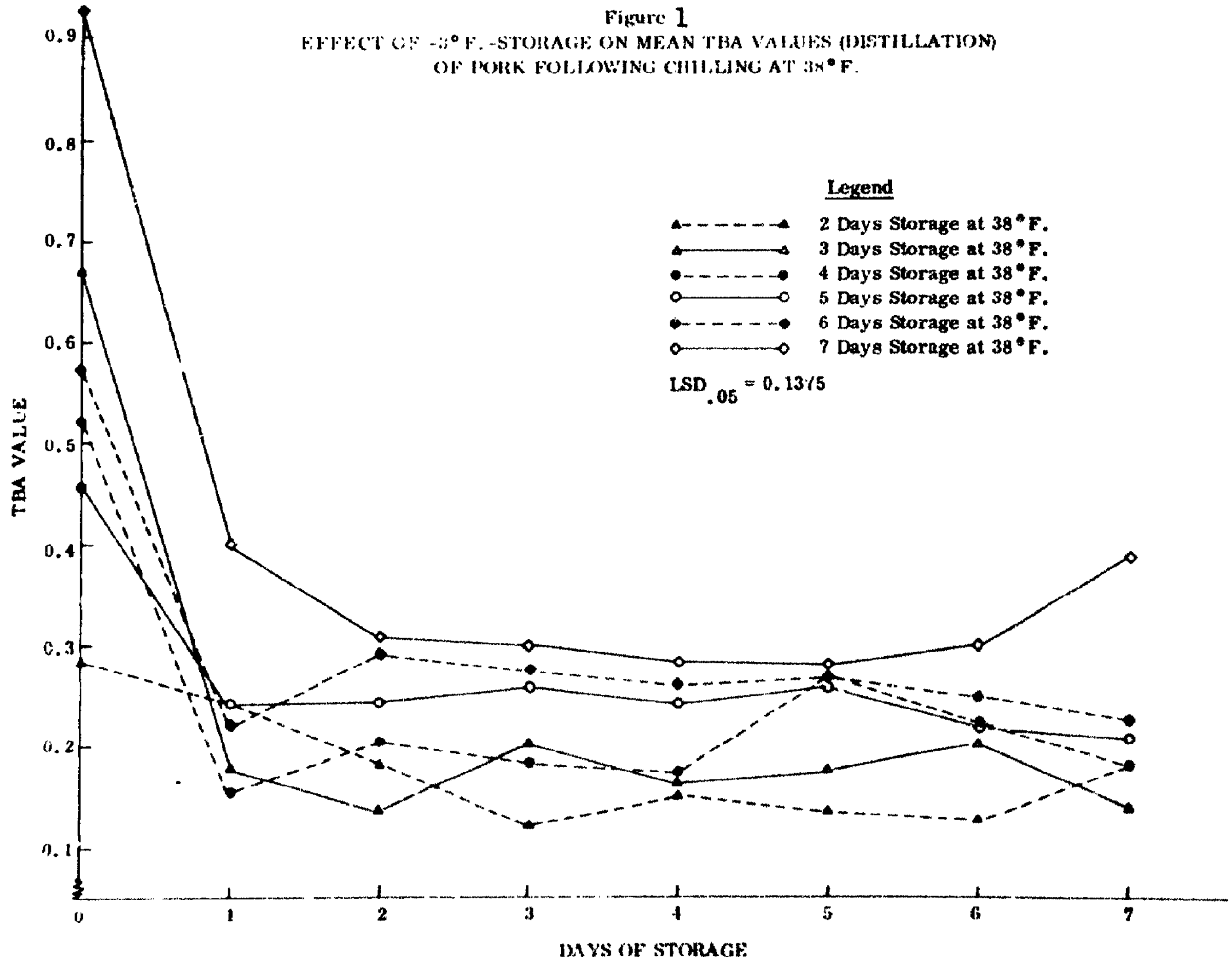


Figure 2

EFFECT OF -3° F. -STORAGE ON MEAN TBA VALUES (EXTRACTION) OF PORK FOLLOWING CHILLING AT 38° F.

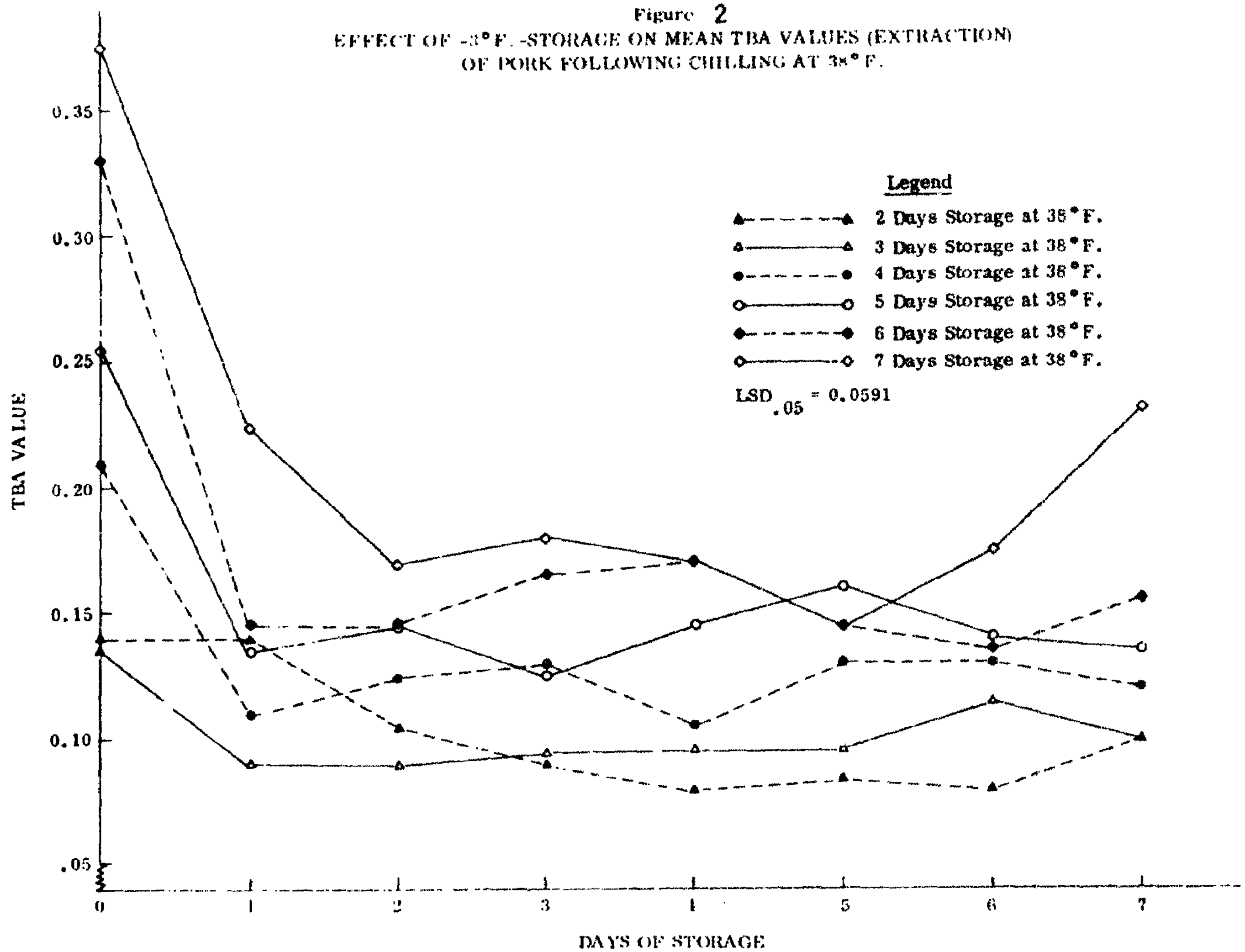


Figure 3

EFFECT OF -3° F. -STORAGE ON MEAN TBA VALUES (EXTRACTION) OF BEEF FOLLOWING CHILLING AT 38° F.

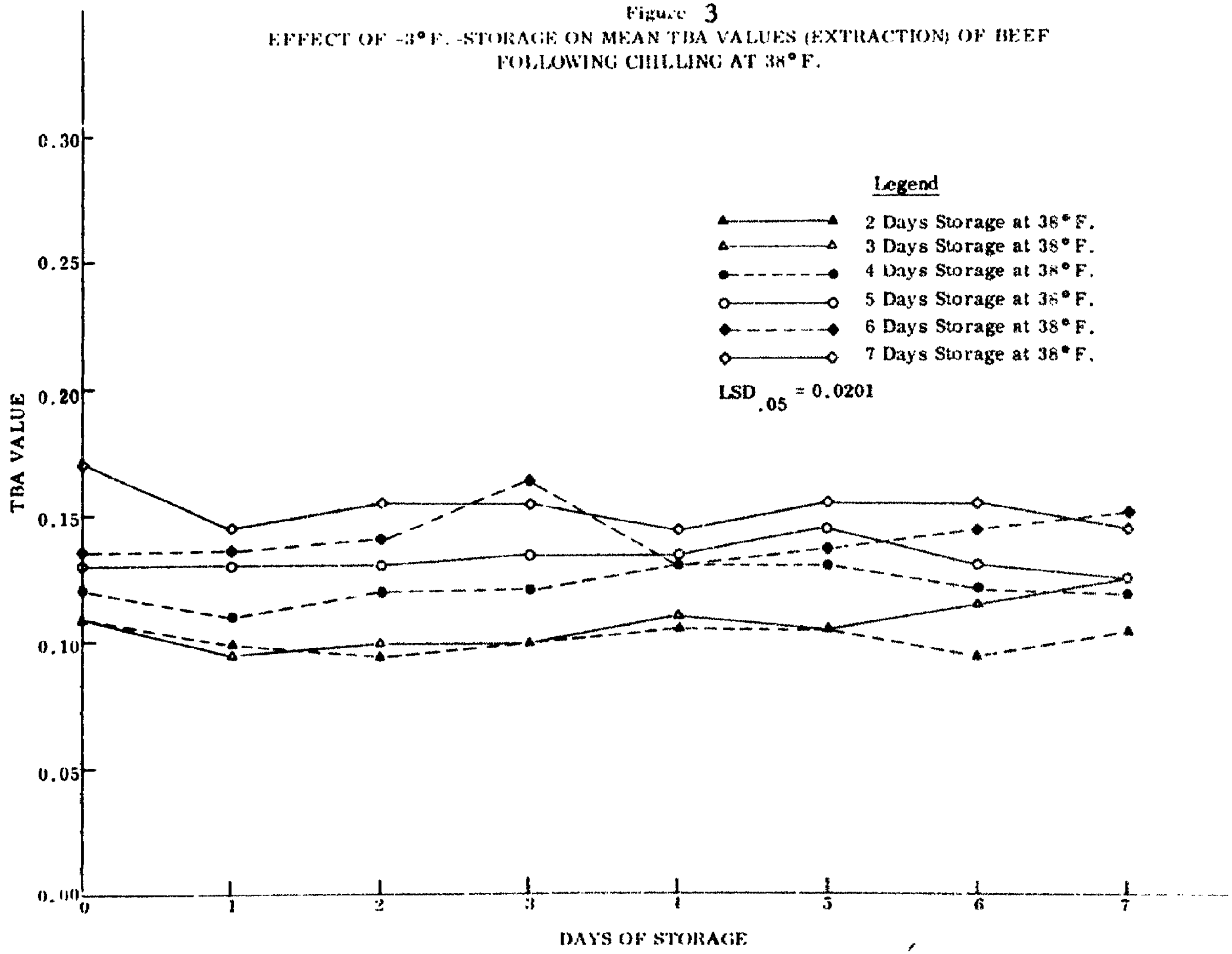


Figure 4

SIMPLE REGRESSION OF TBA VALUES (DISTILLATION) WITH TBA VALUES (EXTRACTION) OF PORK

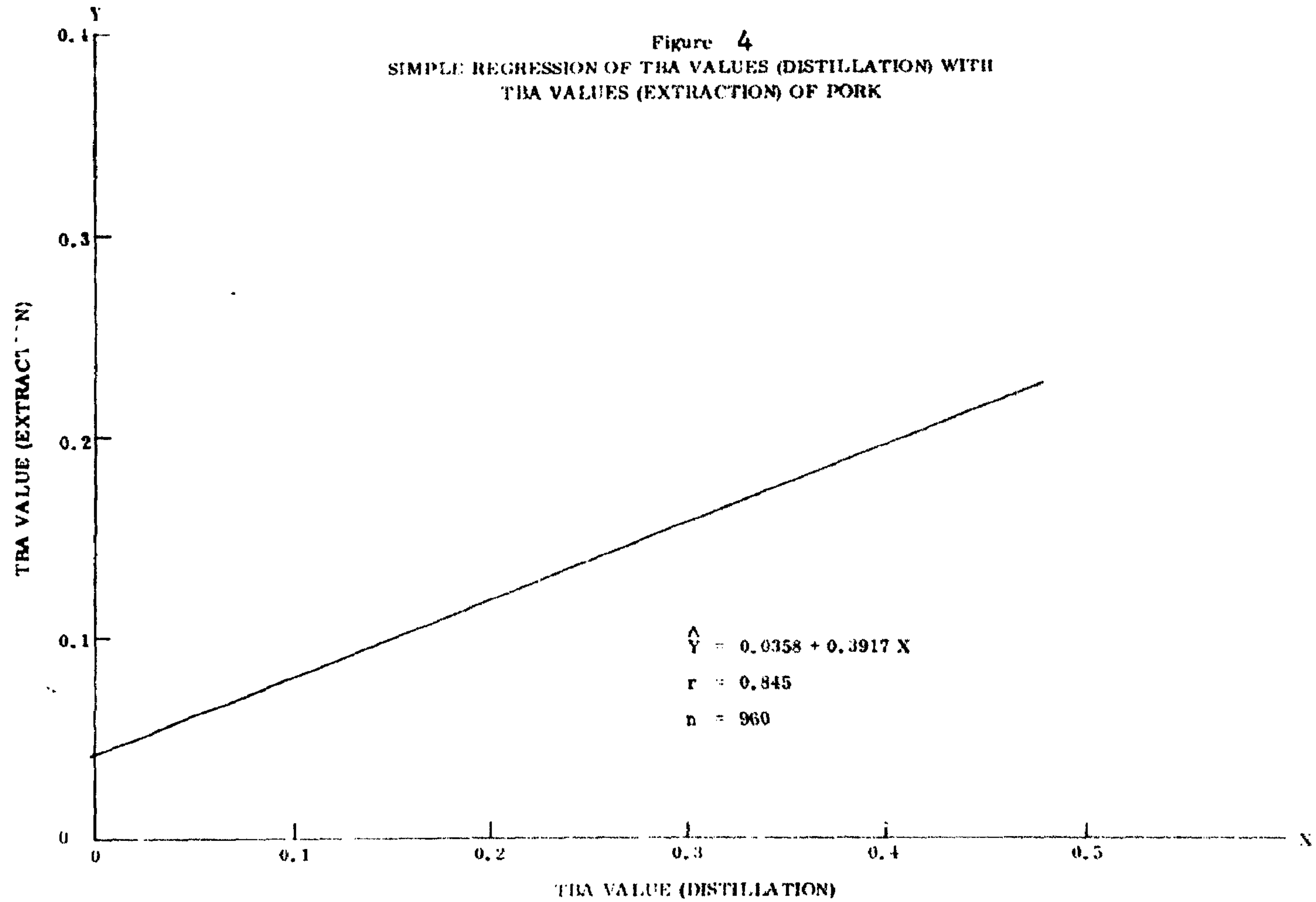


Figure 5
SIMPLE REGRESSION OF TBA VALUES (EXTRACTION)
WITH pH OF PORK

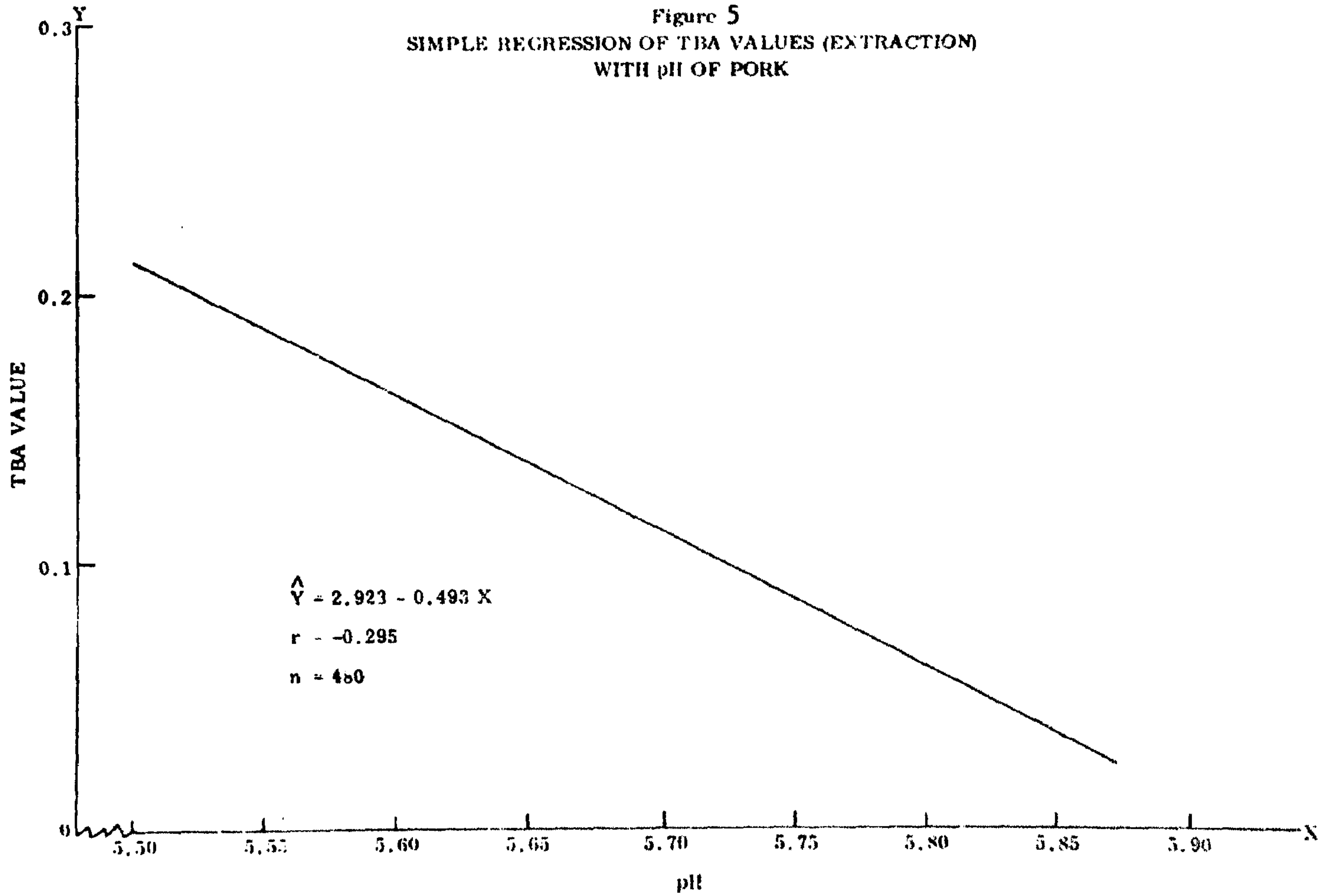


Figure 6
SIMPLE REGRESSION OF TBA VALUES (EXTRACTION) WITH 38°F.-STORAGE OF PORK

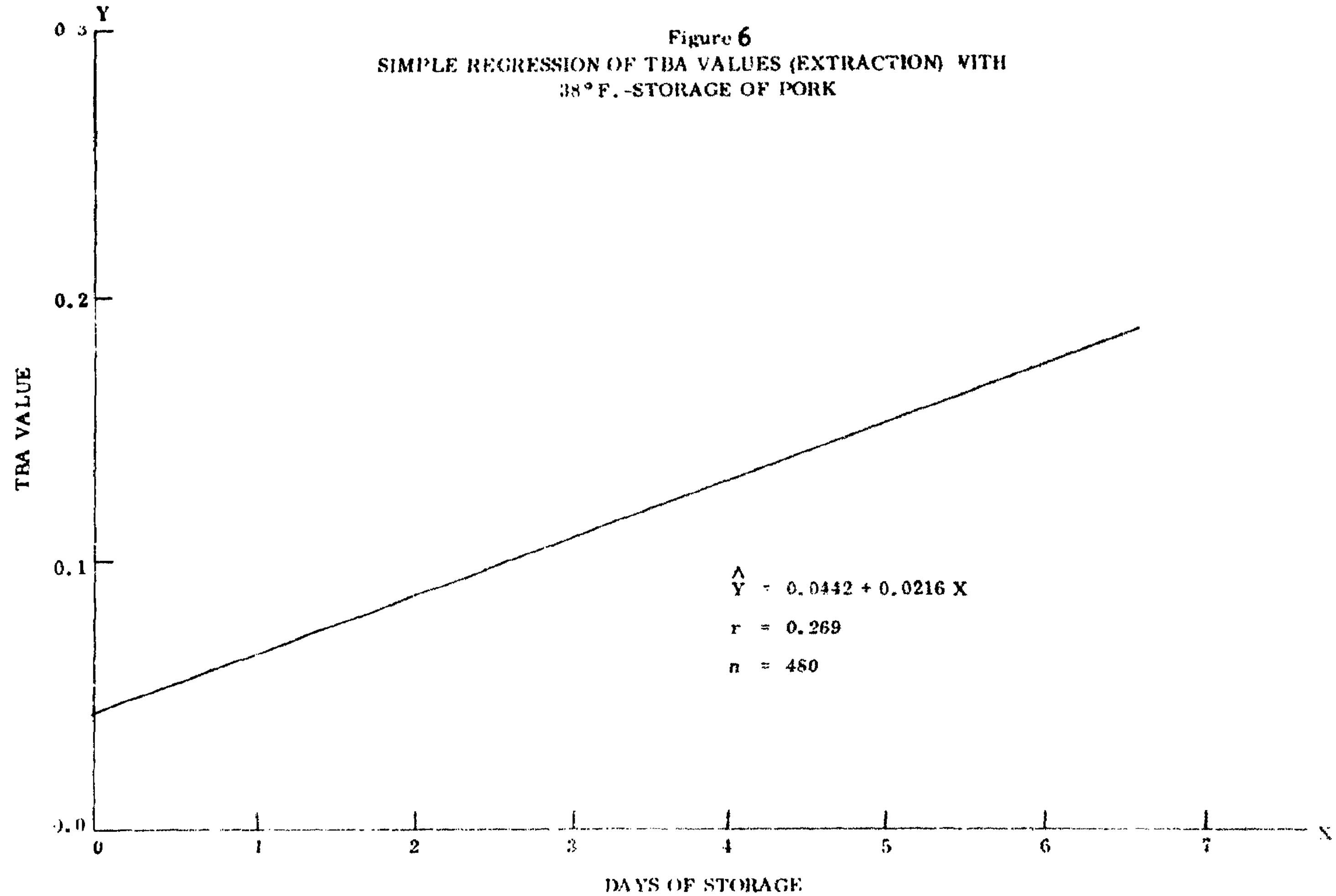


Figure 7
SIMPLE REGRESSION OF TBA VALUES (EXTRACTION)
WITH pH OF BEEF

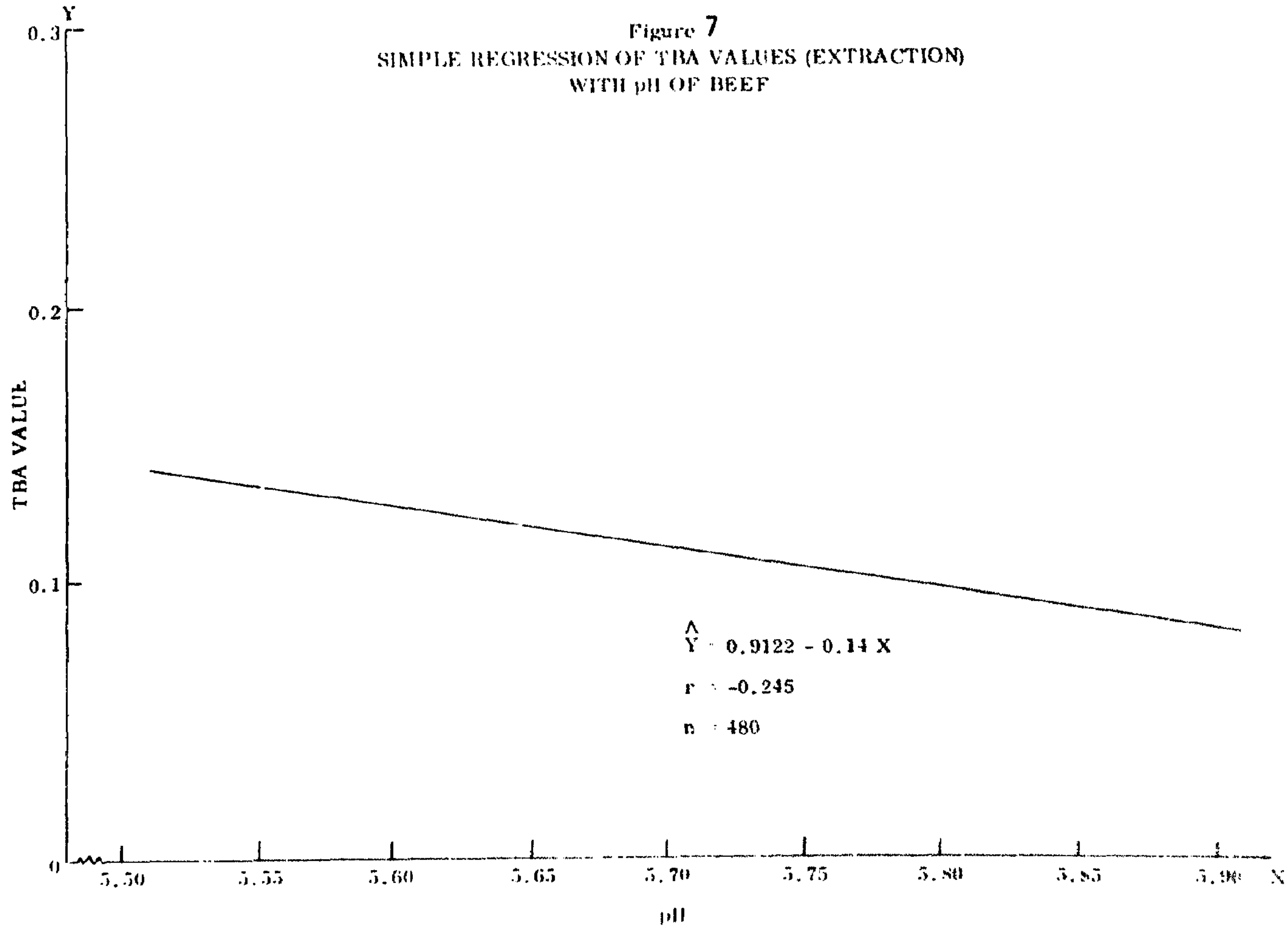


Figure 8
SIMPLE REGRESSION OF TBA VALUES (EXTRACTION) WITH PERCENT FAT OF BEEF

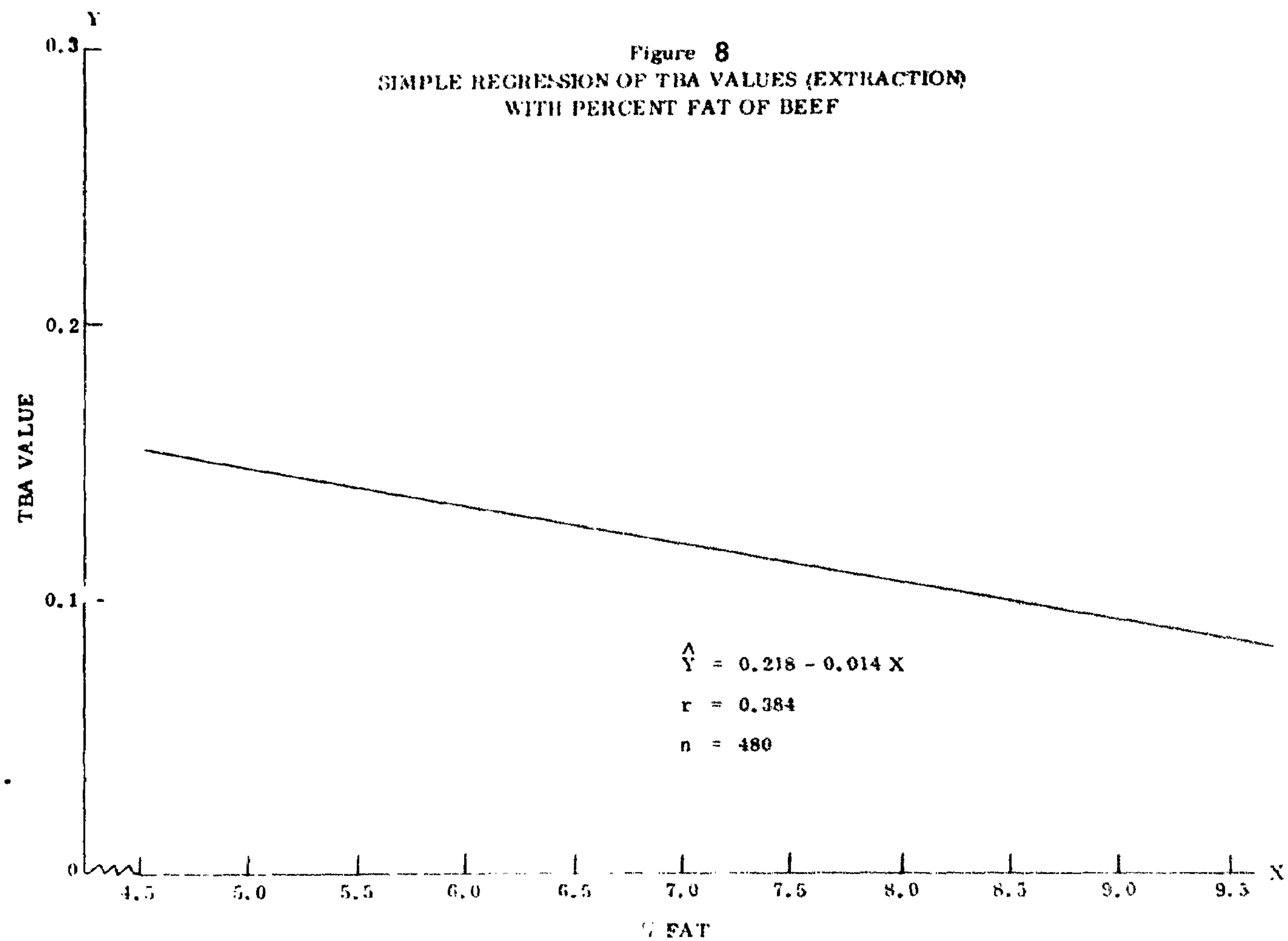
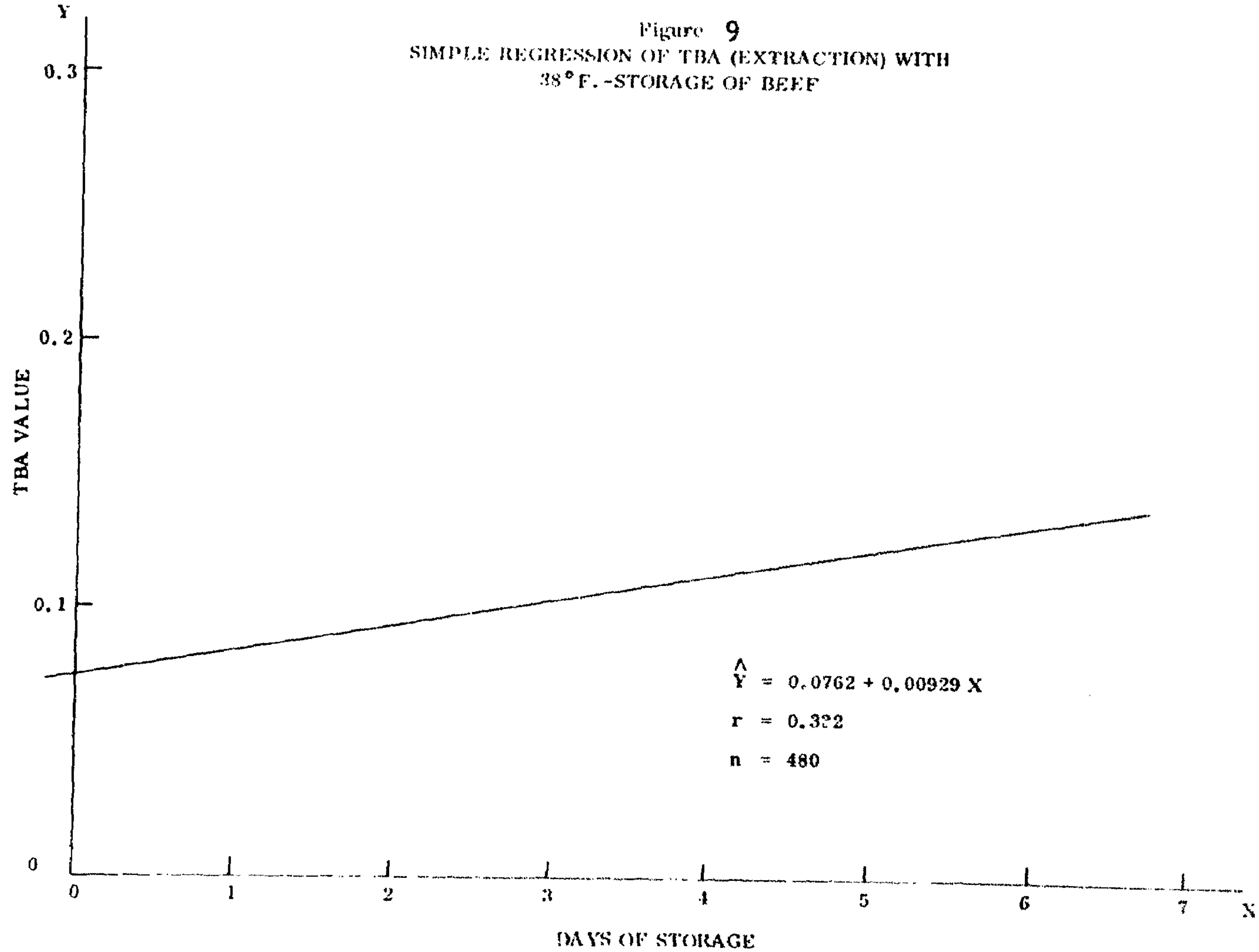


Figure 9
SIMPLE REGRESSION OF TBA (EXTRACTION) WITH
38°F.-STORAGE OF BEEF



Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author) University of Missouri Columbia, Missouri	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

3. REPORT TITLE

CHANGES IN TBA VALUE OF MEAT UNDER CONTROLLED CONDITIONS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final Report 30 June 65 - 31 December 65

5. AUTHOR(S) (Last name, first name, initial)

M. E. Bailey, V. C. Witte, G. F. Krause

6. REPORT DATE April 1967	7a. TOTAL NO. OF PAGES 55	7b. NO. OF REFS 6
8a. CONTRACT OR GRANT NO. DA19-129-AMC-638(N) b. PROJECT NO. 5174240625 c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) 67-67-FD FD-55	

10. AVAILABILITY/LIMITATION NOTICES

Distribution of this document is unlimited.
Release to CFSTI is authorized.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY U. S. Army Natick Laboratories Natick, Massachusetts 01760

13. ABSTRACT

This report summarized work done to determine the effects of cooler and freezer storage on TBA values of ground uncooked pork and beef and their relationship to pH and percent fat. TBA values of pork were determined by distillation and extraction methods and those of beef were determined by the latter method. The TBA values determined were relatively low during storage from 2 to 7 days at 38°F and from 1 to 7 days at -3°F. There were significant animal differences in beef and pork in TBA values, percent fat and pH. There were significant changes in TBA values due to 38°F - storage, pH and percent fat, but changes during freeze-storage were insignificant.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

Unclassified
Security Classification

14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Determination	8					
Oxidation	9		7			
Beef	9		7		9	
Pork	9		7		9	
Thiobarbituric acid (TBA)	10				7	
Tests	10				7	
Raw	8		0		0	
Storage			6		6	
Cooling			6			
Freezing			6			
PH					6	
Fats					6	

INSTRUCTIONS

1. ORIGINATING ACTIVITY: Enter the name and address of the contractor, subcontractor, grantee, Department of Defense activity or other organization *(corporate author)* issuing the report.

2a. REPORT SECURITY CLASSIFICATION: Enter the overall security classification of the report. Indicate whether "Restricted Data" is included. Marking is to be in accordance with appropriate security regulations.

2b. GROUP: Automatic downgrading is specified in DoD Directive 5200.10 and Armed Forces Industrial Manual. Enter the group number. Also, when applicable, show that optional markings have been used for Group 3 and Group 4 as authorized.

3. REPORT TITLE: Enter the complete report title in all capital letters. Titles in all cases should be unclassified. If a meaningful title cannot be selected without classification, show title classification in all capitals in parenthesis immediately following the title.

4. DESCRIPTIVE NOTES: If appropriate, enter the type of report, e.g., interim, progress, summary, annual, or final. Give the inclusive dates when a specific reporting period is covered.

5. AUTHOR(S): Enter the name(s) of author(s) as shown on or in the report. Enter last name, first name, middle initial. If military, show rank and branch of service. The name of the principal author is an absolute minimum requirement.

6. REPORT DATE: Enter the date of the report as day, month, year, or month, year. If more than one date appears on the report, use date of publication.

7a. TOTAL NUMBER OF PAGES: The total page count should follow normal pagination procedures, i.e., enter the number of pages containing information.

7b. NUMBER OF REFERENCES: Enter the total number of references cited in the report.

8a. CONTRACT OR GRANT NUMBER: If appropriate, enter the applicable number of the contract or grant under which the report was written.

8b, 8c, & 8d. PROJECT NUMBER: Enter the appropriate military department identification, such as project number, subproject number, system numbers, task number, etc.

9a. ORIGINATOR'S REPORT NUMBER(S): Enter the official report number by which the document will be identified and controlled by the originating activity. This number must be unique to this report.

9b. OTHER REPORT NUMBER(S): If the report has been assigned any other report numbers *(either by the originator or by the sponsor)*, also enter this number(s).

10. AVAILABILITY/LIMITATION NOTICES: Enter any limitations on further dissemination of the report, other than those imposed by security classification, using standard statements such as:

(1) "Qualified requesters may obtain copies of this report from DDC."

(2) "Foreign announcement and dissemination of this report by DDC is not authorized."

(3) "U. S. Government agencies may obtain copies of this report directly from DDC. Other qualified DDC users shall request through
________________ ________________."

(4) "U. S. military agencies may obtain copies of this report directly from DDC. Other qualified users shall request through
________________________________."

(5) "All distribution of this report is controlled. Qualified DDC users shall request through
________________________________."

If the report has been furnished to the Office of Technical Services, Department of Commerce, for sale to the public, indicate this fact and enter the price, if known.

11. SUPPLEMENTARY NOTES: Use for additional explanatory notes.

12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

Unclassified
Security Classification